Major activities of acid deposition monitoring network in East Asia (EANET) and related studies

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Summary. In order to act against acid deposition problems in East Asian regions, the Acid Deposition Monitoring Network in East Asia (EANET) was established on the decision at the First Intergovernmental Meeting in 1998 among participating countries including China, Indonesia, Japan, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand and Viet Nam. Based on the decision, the preparatory phase activities of EANET were started from 1998, and finished successfully in 2000. From January 2001, the regular phase activities were started. Major activities of EANET are, 1) to implement the national monitoring of acid deposition, 2) to develop and implement the QA/QC (quality assurance/quality control) programs, 3) to develop and implement training programs, etc. The acid deposition monitoring covers four environmental media; wet deposition, dry deposition, soil and vegetation, and inland aquatic environment.

In addition to the mentioned activities, Network Center for EANET has joint research projects among participating countries of EANET. As one of them, joint project with Mongolia was performed to accumulate information on plant sensitivity to acid deposition in Ulaanbaatar, which will be reviewed briefly.

Key words. EANET, Monitoring, Wet and dry deposition, Soil and vegetation, Plant sensitivity, Joint research, Mongolia

1. Results on the acid deposition monitoring

1.1 Wet deposition monitoring

During the preparatory phase for 2 and a half year since 1998, wet deposition monitoring for EANET was performed at 38 sites, including 16 remote, 8 rural and 14 urban sites (Interim Scientific Advisory Group of EANET, 2000).

Table 1 shows annual mean pH of precipitation and wet deposition amounts of major components obtained in 2000. The data were collected in urban, rural and remote sites in a whole year round without any trouble. Annual mean pH of precipitation was in the range of 4.22-6.42. Wet deposition amounts in mmol m^{-2} $year^{-1}$ of major components were in the range of 2.16-239 in non-sea-salt SO_4^{2-} (nss-SO_4^{2-}), 3.04-92.9 in NO_3^-, 0.94-

Plant Responses to Air Pollution and Global Change
Edited by K. Omasa, I. Nouchi, and L. J. De Kok (Springer-Verlag Tokyo 2005)

136 in non-sea-salt Ca^{2+} (nss-Ca^{2+}), 3.47-235 in NH_4^+, and 0.17-153 in H^+, respectively. Underlined data in the table show the extreme value in each column. 'Data Report on the Acid Deposition in the East Asian Region 2000' was published in November 2001 (Network Center for EANET, 2001).

Table 2 indicates the example of difference among urban, rural and remote sites in wet deposition data in China and Russia in 2000. Results of the annual average of rainwater pH and of wet deposition amount of nss-SO_4^{2-} at the monitoring sites in the participating countries of EANET in 2001 are shown in Fig. 1.

Table 1. Annual mean pH of precipitation and wet deposition amount of major components in EANET (2000).

Characteristics of sites	Country	Name of sites	pH	nss-SO_4^{2-} *	NO_3^-	NH_4^+	nss-Ca^{2+} **	H^+
				mmol/m^2				
Urban	China	Guanyinqiao	4.33	163	45.5	174	67.9	50.5
	China	Shizhan	5.68	198	48.6	235	128	1.17
	China	Hongwen	4.72	28.5	28.4	47.9	9.59	29.0
	China	Xiang Zhou	5.15	40.3	31.8	41.7	41.3	14.2
	China	Zhuxian Cavern	4.64	82.4	59.6	90.7	43.2	40.8
	Malaysia	Petaling Jaya	4.35	79.3	92.9	149	23.0	153
	Philippines	Metro Manila	5.48	87.0	48.9	143	56.0	13.2
	Russia	Irkutsk	5.11	15.8	11.2	17.2	14.8	4.15
	Thailand	Bangkok	4.95	24.4	24.8	47.4	12.9	12.8
	Thailand	Samutprakarn	4.83	24.4	15.1	31.1	10.6	14.5
	Vietnam	Hoa Binh	5.11	29.4	18.3	15.2	24.2	14.7
Rural	China	Nanshan	4.22	164	52.4	132	69.3	76.2
	China	Weishuiyuan	6.42	239	42.9	190	136	0.17
	Japan	Ijira	4.52	50.1	64.8	63.8	17.0	80.7
	Philippines	Los Banos	5.44	22.4	14.3	35.9	16.3	9.58
	Russia	Listvyanka	5.07	6.67	8.25	7.29	5.61	3.78
	Thailand	Patumthani	5.25	18.1	17.8	36.6	12.3	5.41
	Vietnam	Hanoi	5.45	36.5	20.2	34.5	25.7	4.48
Remote	China	Dabagou	5.42	116	24.1	165	102	3.14
	China	Xiaoping	4.91	22.0	22.8	31.0	0.94	19.1
	Japan	Happo	4.73	28.1	24.3	31.0	8.12	40.6
	Japan	Oki	4.64	20.4	22.4	23.5	9.07	27.6
	Japan	Yusuhara	4.71	28.4	19.7	14.2	6.80	54.7
	Japan	Ogasawara	5.23	6.22	4.73	4.62	4.24	11.7
	Japan	Hedo	5.13	17.1	16.7	21.0	2.35	21.5
	Malaysia	Tanah Rata	4.79	12.5	10.4	129	6.93	50.4
	Russia	Mondy	5.26	2.16	3.04	3.47	1.75	1.68
	Thailand	Khao Lam	5.56	2.72	5.06	6.03	4.02	2.41

*nss-SO_4^{2-}: non-sea-salt SO_4^{2-}, **nss-Ca^{2+}: non-sea-salt Ca^{2+}

Table 2. Site difference of annual mean pH of rainwater and concentration of major components in μmol l^{-1} of nss-SO_4^{2-}, NO_3^-, nss-Ca^{2+}, and H^+ in Xi'an, China (a) and in Russia (b) in 2000.

(a)

Site	pH	nss-SO_4^{2-}	NO_3^-	nss-Ca^{2+}	H^+
Urban (Shizhan)	5.68	353	87	229	2.1
Rural (Weishuiyuan)	6.42	534	95.8	305	0.4
Remote (Dabagou)	5.42	140	29.1	124	3.8

(b)

Site	pH	nss-SO_4^{2-}	NO_3^-	nss-Ca^{2+}	H^+
Urban (Irkutsk)	5.11	29.6	21	27.8	7.8
Rural (Listvyanka)	5.07	15.1	18.7	12.7	8.6
Remote (Mondy)	5.26	7.1	10	5.7	5.5

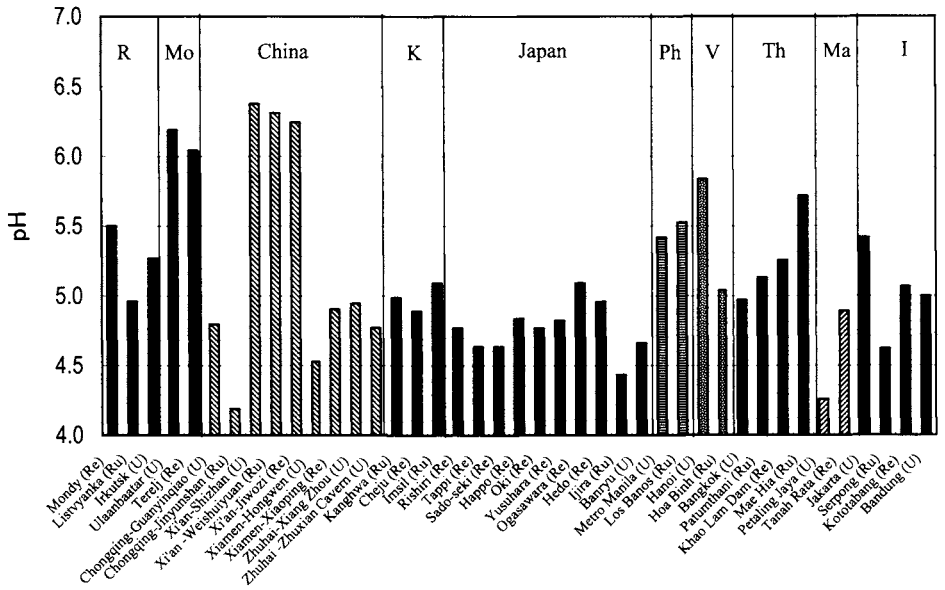

Fig. 1 a. Results of the annual average value of rainwater pH (above figure) in 2001 at the monitoring sites in the participating countries of EANET
Country names abbreviated in the figures: R, Russia; Mo, Mongolia; K; Republic of Korea; Ph; Philippines; V, Viet Nam; Th, Thailand; Ma, Malaysia; I, Indonesia.

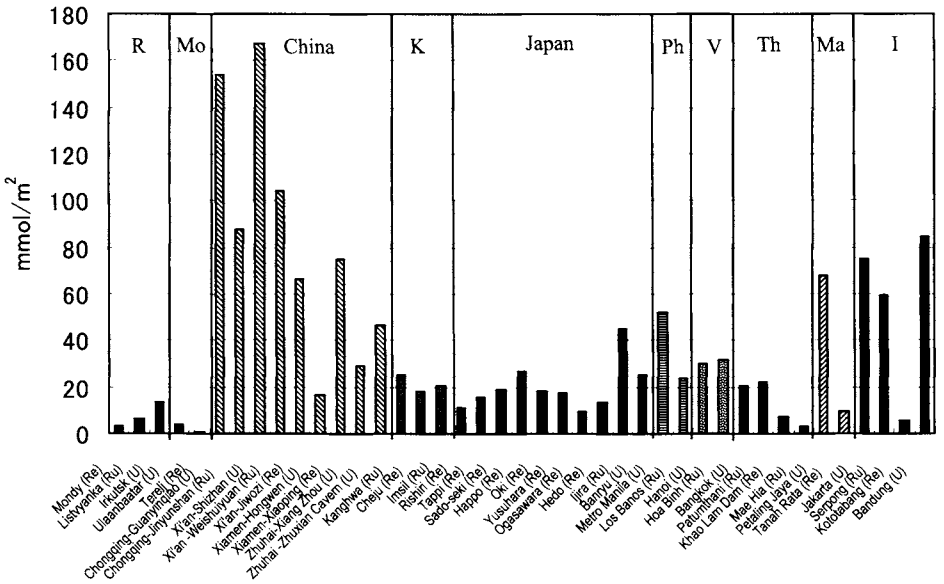

Fig. 1 b. The same as in **Fig. 1 a**, but in annual wet deposition amount of nss-SO_4^{2-}.

1.2 Dry deposition (air concentration) monitoring

For dry deposition monitoring, eight countries including 31 sites (14 remote, 5 rural and 12 urban sites) were participated in 1999. Automatic monitoring method and filter pack method were used to carry out the dry deposition (air concentration) monitoring mainly focusing on the following priority chemical species: First priority: NO_2 (urban), SO_2, O_3, and NO, and particulate mass concentration. Second priority: NO_2 (rural and remote), HNO_3, NH_3, particles (SO_4^{2-}, NO_3^-, NH_4^+, and Ca^{2+}). In case of automatic monitoring method, air concentration monitoring for SO_2, NO_2 (urban), NO, O_3 and particulate matter are available, and an hourly average of these components can be reported.

Four-stage filter pack method was used for EANET filter pack monitoring, with which gaseous (SO_2, HNO_3, HCl, NH_3) and particulate components (SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Ca^{2+}) concentrations were determined. The concentration of parameter obtained by filter packs was calculated from the comparison between extracted solution and standard solution of corresponding chemicals. In 2002, automatic monitoring method was applied in China, Japan, Russia, and Thailand, and filter pack method was used in Indonesia, Japan, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand and Vietnam. Table 3 shows data of air concentration of SO_2, NO_2, and O_3 in ppb in several monitoring sites in 2000. Fig. 2 shows annual average of SO_2 concentration of ambient air in 2002 at 34 monitoring sites in the participating countries.

Data of dry deposition monitoring in 2000, 2001 and 2002 were reported by the Network Center for EANET (2001, 2002, 2003).

Table 3. Data of air concentration (ppb) of SO_2, NO_2 and O_3 in 2000 obtained in several monitoring sites, where the monitoring period was partly limited, as shown in the Table. Nos. 1 and 2 attached in the name of site show the difference of automatic monitor (1) and filter pack (2) methods (adapted from the Network Center for EANET, 2001)

Country	Site	SO_2 ppb	NO_2 ppb	O_3 ppb	Monitoring period
China	Chongqing[1]	48.2*	51.2*	–	*Jan.–Sep.
	Xi'an[1]	6.1	6.3	–	
	Xiamen[1]	5.8*	–	–	*Jan.–Oct.
	Zhuhai[1]	7.1	–	–	
Indonesia	Serpong[1]	2.1*	6.3	–	*Jul–Dec.
Japan	Ijira[1]	0.1	2.1	30.0	
	Banryu[1]	0.6	3.6	35.6	
Malaysia	Tana Rata[2]	N.D.	–	–	
Mongolia	Terelj[2]	0.4	–	–	
	Ulaanbaatar[2]	1.5*	–	–	*Apr.–Oct.
Philippines	Metro Manila[2]	4.8*	–	–	*Jun.–Sep., Nov., Dec.
	Los Banos[2]	0.8*	–	–	*Sep., Nov., Dec.
Russia	Mondy[2]	0.1	–	–	
	Listvyanka[2]	1.0	–	–	
	Irkutsk[2]	3.4	–	–	
Thailand	Khao Lam[1]	1.3*	2.3*	20.0*	*Mar., Jul., Nov.
	Bangkok[1]	4.3	–	–	
	Samputkarm[1]	4.3*	17.8*	–	*May–Dec.

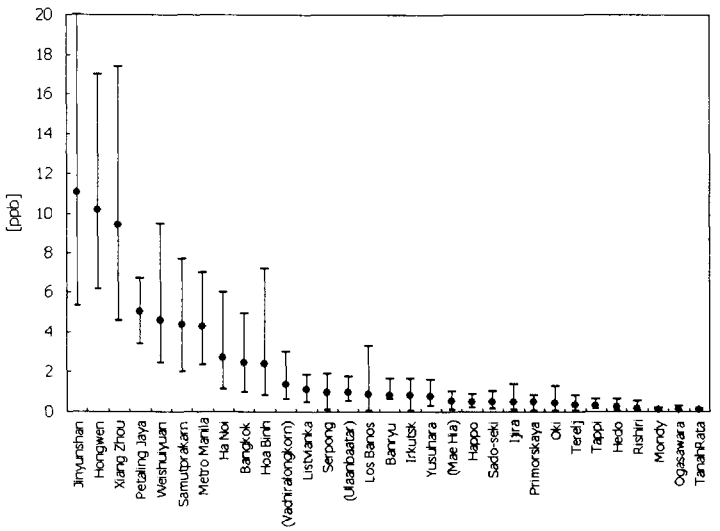

Fig. 2. Annual average of SO_2 concentration of air (max. and mini, monthly average basis) in 2002 at the monitoring sites in the participating countries. "(site name)" in the figure means its annual data completeness under 75%.

1.3 Soil and vegetation monitoring

Forest and (forest) soil monitoring is carried out as a part of the soil and vegetation monitoring in EANET.

Six countries including China, Japan, Malaysia, Philippines, Russia and Thailand performed in 2000 and 2001 their activities on forest and (forest) soil monitoring. In 2002 three countries of Philippines, Russia and Thailand reported the results. One to four areas were selected basically within 50km radius of the acid (wet/dry) deposition monitoring sites in the respective countries. Description of trees (name of species, diameter at breast height and height of trees), understory vegetation survey, and survey of tree decline were carried out in the forest monitoring, and analyses of soil chemical properties such as pH and exchangeable cations were done in the soil monitoring. The surveys are carried out with 3-5 years interval.

As for forest monitoring, most monitoring forests are secondary forest or natural forest, and consist of several tree species. Tree species are varied from coniferous species (e.g. *Pinus sibirica*) in sub-arctic zone to rain forest species (e.g. Dipterocarpaceae family) in tropical zone. Tree decline symptoms have been observed only in the sites of Japan and Russia, however, it seemed that natural environmental factors, such as insect attack, heavy snow, steep slope, and poor soil, might be main causes. No obvious evidence on implication between acid deposition/air pollution and tree decline has reported.

As for soil monitoring, sixteen soil types (by soil unit in the FAO/UNESCO classification) have been identified for the monitoring plots although several soil types (units) have not been identified by the FAO/UNESCO classification. Ten areas have monitoring forests with two (or more) soil types respectively according to the recommendation in the Technical Manual. Monitoring of two soil types (with different chemical properties) in an area would be informative for comparison of their sensitivities to acid deposition. The condition of forest soil in East Asia could be discussed several years later with the data accumulated.

As of 2004, the Data Report 2001 and 2002 including data of twelve monitoring forests during the regular phase which was started from 2001, were disclosed (Network Center for EANET, 2002, 2003), and a part of data in other monitoring forests during the preparatory phase (1998 – 2000) were also published in the previous reports (Network Center for EANET, 2001).

2. Joint research project with Mongolia

2.1 Field survey

In Bogdkhan Mountain around Ulaanbaatar, Mongolia, decline of larch trees (*Larix sibirica*) has been reported, and it might be due to air pollution from the thermal power plants. A number of useful plant (grass) species also grows in the mountainous area, and effect of the air pollution on those plant species should be studied.

Fig. 3 shows the locality of field survey sites in Ulaanbaatar, Mongolia. Surveys on air concentrations by passive samplers, field observation of tree decline and chemical

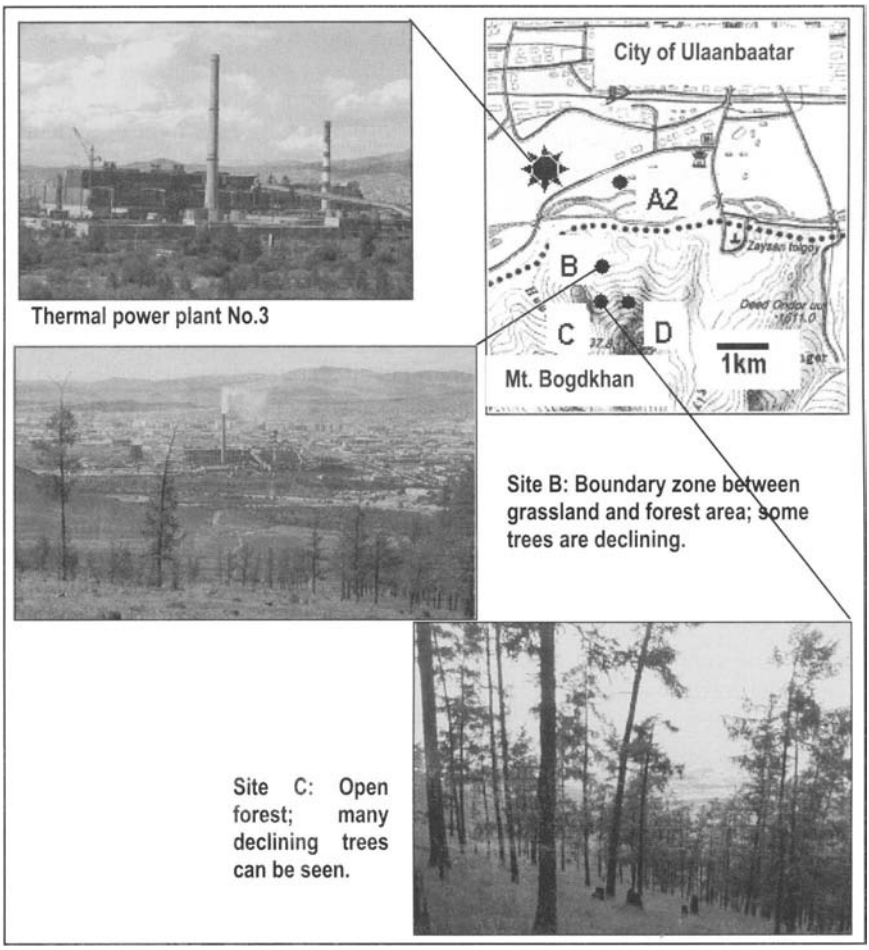

Fig. 3. Study site of joint research project in Ulaanbaatar, Mongolia.

properties of needles/soils were carried out in 2001 and 2003 in Bogdkhan Mountain in order to obtain information on implication between the air pollution and chemical/ (eco-) physiological properties on plant and soil. Tree decline was observed not only on the sites B and C in Fig. 3, 2-3 km far from the thermal power plant No. 3 (capacity, 300 MW; no treatment system for SO_x/NO_x emission), but also in reference forests because of insect attack. However, decline symptoms observed on the slope were different from those in the reference forests. In mid summer 2001, concentrations of all the pollutants except O_3 were not high; less than 5 ppb (average concentration of two weeks), but O_3 concentration was relatively high in mid summer and gradually decreased from autumn to winter (ca. 40 ppb). From autumn to winter, concentrations of NO_x increased probably due to increasing of combustion of coal/wood in winter. Mean concentrations of SO_2 and

O_3 during the sampling period (July to November) of the year 2003 were higher at the sites on the slope than at other sites. In addition, sulfur contents of larch needles were also higher on the slope than other sites. It was suggested that the slope facing the thermal power plant have stronger effects than the other areas. Soil acidification due to acid deposition may hardly occur because of the high concentration of base cations; e.g. pH (H_2O): 5.8, exchangeable Ca: 22.6 cmol(+) kg^{-1} in a site on the slope. Direct effects of air pollution, especially effects of O_3, should be considered as one of the possible causes for the tree decline on the slope as well as natural environmental factors such as insect attack.

It was clarified that air pollutants such as SO_2 and O_3 were transported to Bogdkhan Mountain, and the slope facing the thermal power plant had larger effects of the pollution than the reference forest area. Concentration of SO_2 was very low but O_3 was relatively high. Effects of air pollution, especially the effect of O_3, should be considered as one of the possible causes for tree decline though effect of insect attack might be the major cause as observed in large extent of Bogdkhan Mountain. As for the surveys, detailed description was reported by Sase et al. (2005).

2.2 Gas exposure experiment for plant sensitivity test

Increasing of air pollution level in Ulaanbaatar, Mongolia has caused great concerns in the stability of some semiarid grassland ecosystems. So far, there is no experimental datum available for assessing the effects of air pollutants on the native grass species in this region. In our recent study, five Mongolian semiarid plant species of *Astragalus* spp., *Carex* spp., *Chamaenerion angustifolium*, *Polygonum alopecuroides* and *Sanguisorba officinalis*, were grown for 4 weeks from the seeds collected at Mt. Bogdokhan. They were exposed to either O_3 (0.05 ppm in daily average, 0.1 ppm for 3 hours in the daytime) or SO_2 (0.1 ppm constant) for 4 weeks in the naturally-lit environment controlled chambers. The chambers were maintained 25/15°C (14hr day/10hr night) and 55/75% (day/night, rel. humidity). So as to investigate the growth responses of these species to O_3 and SO_2, growth parameters such as leaf number, leaf area, biomass and root/shoot ratio were measured at the final harvest. Different species showed different sensitivities to O_3 and SO_2. O_3 significantly reduced leaf number of *Carex* spp., biomass and root/shoot ratio of *Polygonum alopecuroides*, and root/shoot ratio of *Sanguisorba officinalis*, however O_3 had no effect on other parameters of these species or all the parameters of the other species. SO_2 significantly reduced leaf number and biomass of *Carex* spp., and had no effects on other parameters for this species and all the parameters of the rest of the four species. Results in detail were reported by Shimizu et al. (2005).

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